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Scalable and Vision Free User Interface Approaches for Indoor Navigation Systems for the Visually Impaired

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SCALABLE AND VISION FREE USER INTERFACE APPROACHES FOR INDOOR NAVIGATION SYSTEMS FOR THE VISUALLY IMPAIRED

A Thesis Presented

by

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ABSTRACT

SCALABLE AND VISION FREE USER INTERFACE APPROACHES FOR INDOOR NAVIGATION SYSTEMS FOR THE VISUALLY IMPAIRED

FEBRUARY 2015

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This thesis introduces scalable and vision free user interface approaches for indoor navigation systems for the visually impaired. Using an Android Smartphone that runs the indoor navigation system – Percept Application with accessibility features, the blind user obtains navigation instructions generated automatically by our navigation generation algorithm to the chosen destination when touching specific landmarks tagged with Near Field Communication tags. This thesis also introduces an Orientation & Mobility Survey Tool that can help O&M Instructors survey the building and deploy such indoor navigation system. The system was deployed and tested in a large building at the University of Massachusetts at Amherst.

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CHAPTER 1

INTRODUCTION

The World Health Organization (2010) reported that 285 million people are visually impaired worldwide, of whom 39 million are blind and 246 have low vision [1]. Based on data from the 2004 National Health Interview Survey, 61 million Americans are considered to be at high risk of serious vision loss if they have diabetes, or had a vision problem, or are over the age of 65 [2]. As documented by the American Diabetes Association, diabetes is the leading cause of new cases of blindness among adults aged 20–74 years. In 2005-2008, 4.2 million (28.5%) people with diabetes aged 40 years or older had diabetic retinopathy, and of these, almost 0.7 million (4.4% of those with diabetes) had advanced diabetic retinopathy that could lead to severe vision loss [3].

Since vision is the most important organ to sense the surroundings, its loss can significantly reduce the visually impaired individual orientation and mobility, especially in unfamiliar and complex indoor environments. Even with the help of a guide dog or cane, it is still a challenge for the visually impaired to independently navigate in such unfamiliar environments without help from sighted individuals. It is commonly accepted that the incapability of moving freely and independently can hinder the full integration of an individual into society [4].

Our contributions include designing an indoor navigation system for visually impaired and blind people with scalability feature. It has navigation instruction generation algorithm, a vision-free smartphone user interface and Orientation & Mobility (O&M) Survey Tool. Scalability means that the system could be deployed in indoor environment of any size or layout with the same navigation instruction generation algorithm and system architecture.

CHAPTER 2

LITERATURE SURVEY

There have been a number of research projects that can help the visually impaired navigate in unfamiliar indoor environments [5-27]. We provide a description of each approach while focusing on the following features:

- Localization Technology
- Infrastructure Required
- Technology Developed
- Testing with Human Subjects
- *Scalability of the approach which includes:*
    - *Automatic Generation of Navigation Instructions*
    - *Smartphone Accessible User Interface*
    - *Orientation & Mobility (O&M) Survey Tool*

In [5] the authors present a system which integrates a geographic information system of a building with visual landmarks for localizing the user in the building and for tracing and validating a route for the user's navigation. The system works in real-time on a netbook computer and it was tested successfully in the campus building. Most planned routes could be followed from the start to the destination, even when these were on different floors. The few planned routes, which caused problems, were due to a lack of landmarks at a certain location. However, after finding a new start position by walking about to a location with multiple landmarks, the updated routes could also be accomplished. No navigation instruction details provided. The paper does not address the approach scalability.

In [6] the authors developed a robust and efficient algorithm to detect doors, elevators, and cabinets based on their general geometric shape, by combining edges and corners. Then, to distinguish intra-class objects (e.g. an office door from a bathroom door), they extract and recognize text information associated with the detected objects. Then, the object type, orientation, location, and text information are presented to the blind traveler as speech. The paper does not address the approach scalability.

In [7] the authors present an indoor navigation system called Navatar that allows for localization and navigation by exploiting the physical characteristics of indoor environments, taking advantage of the unique sensing abilities of users with visual impairments, and minimalistic sensing achievable with low cost accelerometers available in smartphones. A user study with six blind users determines the accuracy of the approach, collects qualitative experiences and identifies areas for improvement. They found that users could successfully complete 85% of the paths. The paper does not address the approach scalability.

In [8] the authors represent an indoor positioning and navigation system based on measurements of received signal strength in wireless local area network. A navigation module integrated with the tracking system guides users to pre-defined destinations with voice instructions. A pilot study was carried out with 30 visually impaired subjects from the Canadian National Institute for the Blind. Testing results show that the proposed system can be used to guide visually impaired subjects to their desired destinations with a very high success rate. The paper does not address the approach scalability.

In [9] the authors develop an iPad application as part of Otaniemi Open Project. The application helps new visitors in positioning and navigating both indoor and outdoor in Otaniemi campus of Aalto University. In addition to the main features (positioning and navigation), the application also assists users manipulating calendar's scheduled events spatially. A variety of related technologies and methods have been studied to select the best suitable ones for developing the application. The paper basically provides information about comparing different positioning techniques and how those different techniques can be used while considering different factors like accuracy, precision and finances available. The paper does not address the approach scalability.

In [10] the authors present an indoor navigation system that was designed taking into consideration usability as the quality requirement to be maximized. This solution enables one to identify the position of a person and calculates the velocity and direction of his movements. Using this information, the system determines the user's trajectory, locates possible obstacles in that route, and offers navigation information to the user. The solution has been evaluated using two experimental scenarios. The paper does not address the approach scalability.

In [11] the authors introduce a novel navigation mechanism. Such navigation scheme is enriched with user profiles and the adoption of an ontological framework. These enhancements introduce a series of technical challenges that are extensively discussed throughout the paper. The paper does not address the approach scalability.

In [12], Radio Frequency Identification (RFID) has been selected and investigated. A new approach was then be tested in an indoor environment in an office building of the Vienna University of Technology. It could be seen that for a combined positioning of RFID time-based CoO and a low-cost MEMS-based INS positioning accuracies on the 1 to 2 meter level can be achieved. The different experiments performed in the test bed are described and discussed in this contribution. The paper does not address the approach scalability.

The system introduced in [13] consists of short audio signals sent by invisible infrared light beams from permanently installed transmitters to a hand-held receiver that decodes the signal and delivers the voice message through its speaker or headset. To use a Talking Signs system, the user scans the environment with the hand-held receiver. As individual signals are encountered, the user hears the messages. Messages are unique and short, simple and straight forward. The messages repeat, continuously identifying key features in the environment. The paper does not address the approach scalability.

One of the prominent projects that underwent successful user trials with 24 visually impaired subjects is the PERCEPT project which was developed at UMASS Amherst 5G Mobile Evolution Lab [14]. PERCEPT uses passive RFID tags (R-tags) deployed on different landmarks in the environment. PERCEPT user interacts with the environment using a glove and a Smartphone. Upon touching the R-tag using the glove, the Smartphone provides navigation instructions to the visually impaired users.

PERCEPT-II builds on the success of PERCEPT system and differs from it in the following aspects: a) The user carries only a Smartphone (no glove is required), simplifying the interaction with the system and lowering its cost; and b) we developed an Orientation and Mobility (O&M) survey tool that enables the Orientation and Mobility instructor to describe and mark specific landmarks in the building, reducing the system deployment cost. In PERCEPT-II we deploy Near Field Communication (NFC) tags on existing signage at specific landmarks in the environment, e.g. doors, elevators, stairs, etc. The users obtain audial navigation instructions when they touch the NFC tags using their phone. We developed a "vision free" interface on the phone that enables the user to interact with the system using accessibility features built in the Android operating system.

A summary comparison of these papers with PERCEPT-II are provided in Table 2.1 and Table 2.2. As shown in Table 2.1 and Table 2.2, no approach has considered the scalability issues, i.e. there is no discussion of automatic generation of navigation instructions, smartphone accessible user interface and O&M survey tool. In the next subsection we provide a description of PERCEPT-II and focus on my contributions which include scalability features for PERCEPT-II.

Table 2.1: Comparison of indoor navigation approaches

Path	Localization Technology	Infrastructure Required	Technology Developed
Paper [5]	Image Processing	Need to build a picture database beforehand	Algorithm using Machine Learning to do landmark recognition; Developed a data-structure to represent floor structure
Paper [6]	Computer vision	Need to build a picture database beforehand	A device with A camera, a microphone, a portable computer, and a speaker
Paper [7]	Low cost accelerometers available in smartphones	No Infrastructure Required	Android Smartphone
Paper [8]	Wifi Localization	Need to build a database to store Wifi-fingerprints beforehand	Windows Mobile platform PDA
Paper [9]	Wifi Localization	Need to build a database to store Wifi-fingerprints beforehand	iPad
Paper [10]	Image processing	Need to build a picture database and a XML document to store environment objects within the room	The white cane which includes several infrared LEDs
Paper [11]	Not discussed in the paper	No Infrastructure Required; landmark database needed	No
Paper [12]	Active RFID Localization	Need RFID tags; Build RFID fingerprinting signal strength database	portable RFID reader
Paper [13]	Infrared light	Need transmitters & a hand-held receiver	infrared light
Paper [14]	Passive RFID	Customized Glove Smartphone Passive RFID tags	Customized Gloves
Paper [15]	Passive RFID	Smartphone Passive RFID tags	Android Smartphone

Table 2.2: Comparison of indoor navigation approaches

Path	Localization Technology	Infrastructure Required	Technology Developed
Paper [5]	Image Processing	Need to build a picture database beforehand	Algorithm using Machine Learning to do landmark recognition; Developed a data-structure to represent floor structure
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Paper [11]	Not discussed in the paper	No Infrastructure Required; landmark database needed	No
Paper [12]	Active RFID Localization	Need RFID tags; Build RFID fingerprinting signal strength database	portable RFID reader
Paper [13]	Infrared light	Need transmitters & a hand-held receiver	infrared light
Paper [14]	Passive RFID	Customized Glove Smartphone Passive RFID tags	Customized Gloves
Paper [15]	Passive RFID	Smartphone Passive RFID tags	Android Smartphone

We first introduce PERCEPT-II architecture and then highlight our contributions as well as planned contributions.

Fig. 2.1 depicts PERCEPT-II architecture first introduced in [15]. The server hosts the system database as well as the instruction generation module. PERCEPT-II client downloads from the server the navigation instructions and interacts with the user through the "vision free". The O&M survey tool updates the database with the information captured by the tool such as the landmarks and the physical layout of the building (i.e., the building Blueprint). NFC tags are deployed in the environment on existing signage next to the Braille (see Fig. 2.2). Using the Smartphone running PERCEPT-II application the user interacts with the environment by touching the NFC tags.

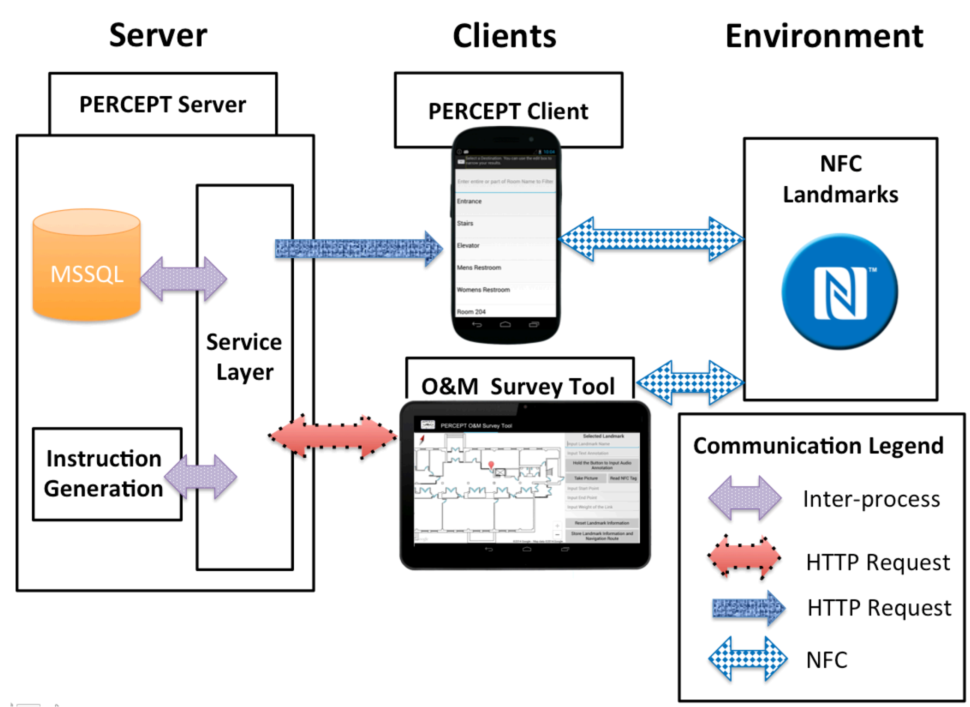

Figure 2.1: PERCEPT-II architecture

Figure 2.2: NFC tag on existing signage

Fig. 2.3 depicts the data flow of the entire system. The entire system is divided into two phases - offline phase and online phase. In the offline phase, O&M Instructors survey the buildings and input landmark information using O&M Survey Tool with building's blueprint provided. And the online phase includes users using Percept accessible user interface to interact with the environment (deployed NFC tags) and receive audible navigation instructions when travelling in the building in real-time. The following are the details of input and output of each module.

The input of O&M Survey Tool are the building's blueprint retrieved from Server's database and landmark information input by O&M Instructor. The output of O&M Survey Tool are node-link structure of the building and landmark information. And the output is transmitted to Server's database.

The input of Navigation Instruction Generation Engine are the node-link structure of the building and landmark information from Server's database. The Instruction Generation Engine uses the input to generate the output, i.e., the navigation instructions.

The input of the Smartphone Accessible User Interface is the navigation instructions and landmark information from Server's Database as well as NFC tag information from the environment. The output of the User Interface is the navigation instructions in audio format presented to the visually impaired users.

Our contributions includes the following modules:

1. Navigation Instruction Generation Algorithm – detailed description is provided in Chapter 3
2. Vision Free User Interface – detailed description is provided in Chapter 4
3. O&M Survey Tool – detailed description is provided in Chapter 5

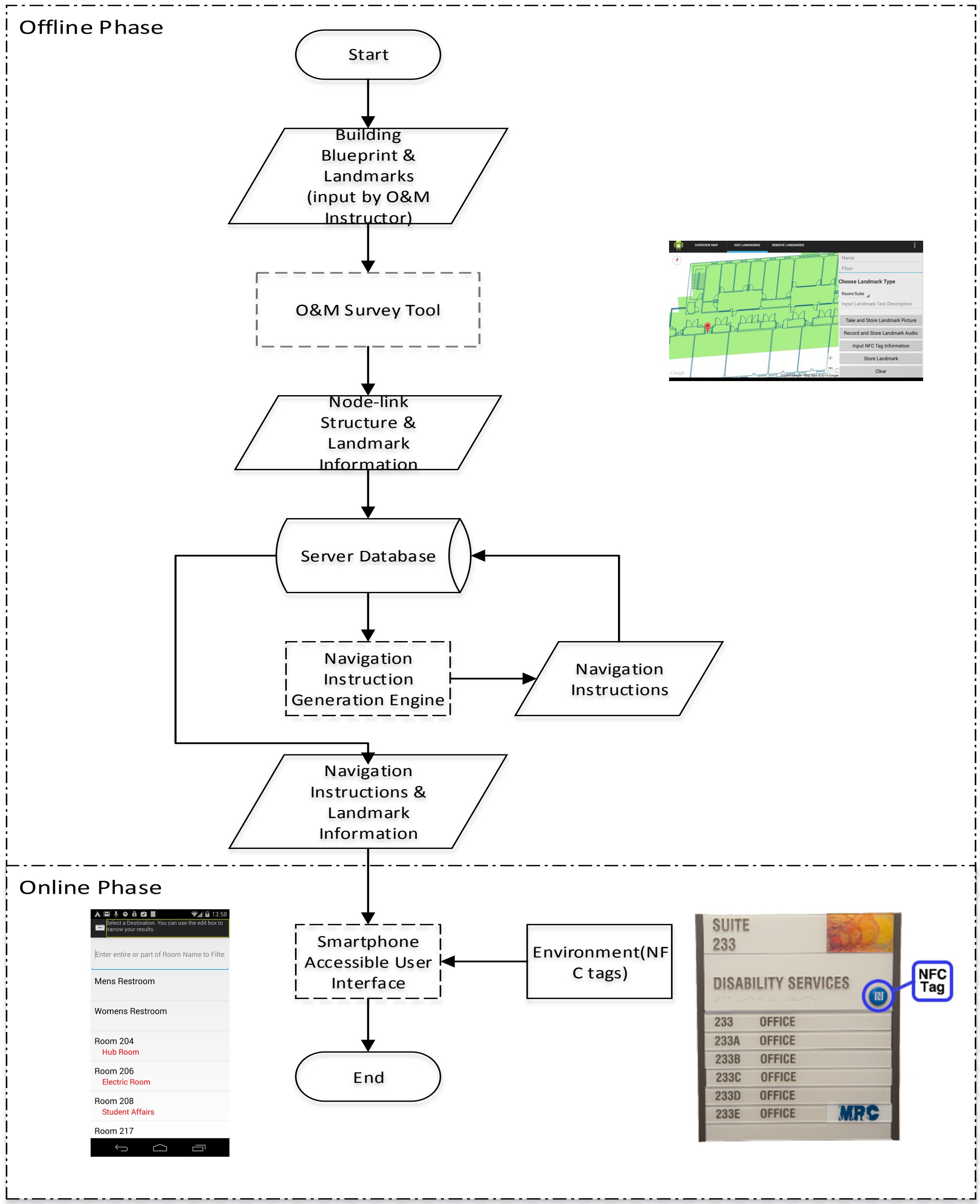

Figure 2.3: System Data Flowchart

The parts in dotted boxes are this thesis' contributions with part of the User Interface.

CHAPTER 3

NAVIGATION INSTRUCTION GENERATION ALGORITHM

In this section we introduce the navigation instruction module. The input to this module as depicted in Fig. 2.3 includes node-link structure and landmark information. The output of this module includes the navigation instructions generated by our navigation instruction module. The navigation instruction generation algorithm is general. It means that the instruction generation engine is not customized for just one specific building. It could be applied to any building or indoor environment regardless of the size and layout. As a result, the system is scalable. Examples of such instructions are provided in Section 3.1. In Section 3.2, we include the vocabulary used in the instruction generation module.

3.1 Navigation Instruction Examples

Fig. 3.1 is the floor plan for the second floor of the Whitmore Building. The following are two examples of navigation instructions.

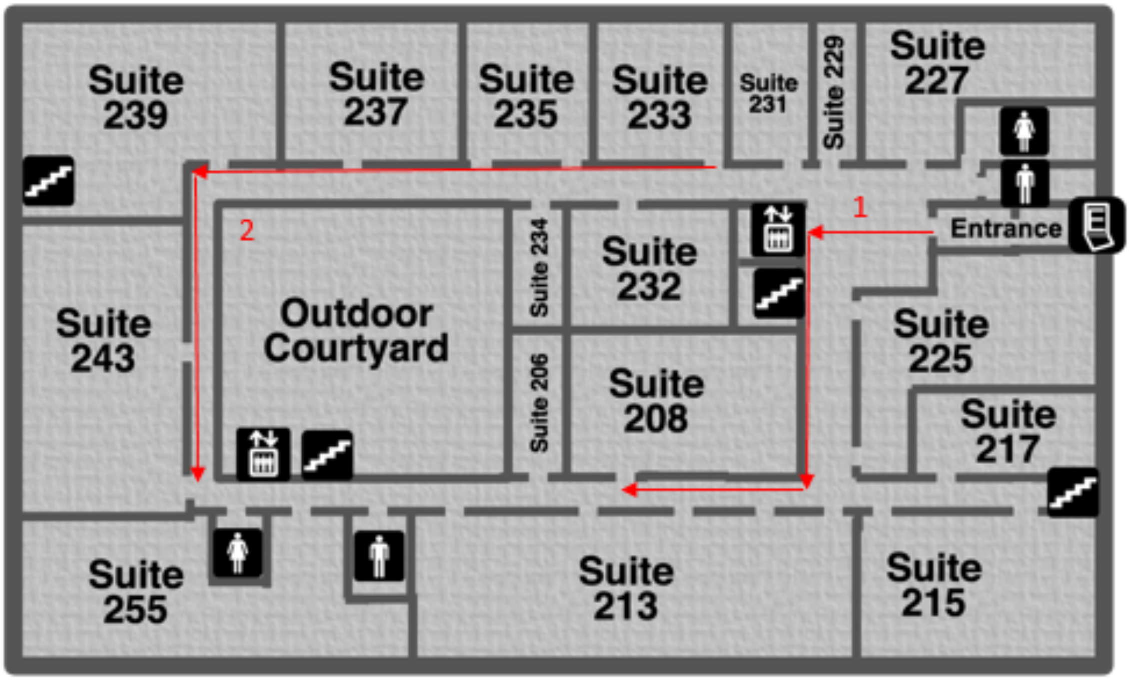

Figure 3.1: Schematics of Floor 2

Example 1: Navigation instructions for Route 1 in Fig. 3.1:

Start Point: Entrance

End Point: Room 208

Navigation Route: Entrance Door, Elevator, Stairs, Suite 208.

Next instruction: Welcome to the Whitmore Building! This is a three story building with a courtyard in the center. There is an elevator and set of stairs to access each level. Your current location is Second Floor North Entrance. Put your back against the door, you are facing the lobby with sitting areas on your left and right hand side, cross the lobby, until you reach the wall. Press Next Instruction Button.

Next instruction: Turn left into the hallway, and follow the wall on your right side. You will pass by computers. Continue until you reach an opening. This is an intersecting hallway. Press Next Instruction Button.

Next instruction: Turn right into the hallway, and follow the wall on your right side. Until you reach the first door, You have reached Room 208. Scan NFC tag or press Next Instruction Button.

Next instruction: You have reached your destination Room 208.

Example 2: Navigation instructions for Route 2 in Fig. 3.1:

Start Point: Suite 233

End Point: Suite 243

Navigation Route: Suite 233, Suite 235, Suite 237, Suite 239, Suite 243

Navigation Instruction: Your current location is Suite 233. Put your back against the door, turn right and follow the wall on your right side. Continue until you reach a wall. This is an intersecting hallway.

Next instruction: Turn left into the hallway, and follow the wall on your right side for 2 doors. You have reached Suite 243. Scan NFC tag or press Next Instruction Button.

Next instruction: You have reached your destination Suite 243.

3.2 Navigation Instruction Vocabulary Description

The following is the vocabulary for navigation instructions,

- Motion Vocabulary

A. Turn right

B. Turn left

C. Continue (Walk straight)

D. Cross (hallway)

E. Walk past (the opening)

- Orientation Adjustment Vocabulary

  A. Put your back against the door/ With the tag to your back

  B. With the tag to your left/right side

  C. Face the tag

- Motion Stop Vocabulary

  A. (Proceed) until reaching an intersecting hallway

  B. (Proceed) until reaching an intersecting wall

  C. (Proceed) until reaching an opening

  D. (Proceed) until reaching a different texture (metal gate)

  E. (Proceed) until reaching a certain number of doors/ passing a certain number of firedoors

  F. (Proceed) until reaching a certain landmark

- Travel-by Vocabulary

  A. pass by obstacles or landmarks

  B. hear certain sound/ smell in the route passing by a certain landmark

  C. trail/follow certain texture (on your left/right side)

  D. keep certain landmark to the left/right side

- Floor-cross Vocabulary

  A. using elevator – press a certain button for the destination floor

  B. using stairs – go up/down certain number of flights

CHAPTER 4

USER INTERFACE

This section will describe smartphone accessible user interface. The user carries an NFC equipped Android Smartphone with a touch screen. Smartphones are showing to be a very beneficial tool for visually impaired users in their daily lives. They use applications such as money reader, object recognition, color recognition, web browsing, reading emails and making calls.

Blind users can access these applications through a touchscreen since the applications interact with the user using accessibility features provided by the Android operating system. Therefore, to enable blind users to access PERCEPT-II application we designed the interface using accessibility features.

"Explore by Touch" is the main Accessibility Service used on Android to facilitate a vision-free use of the device. There are two ways to utilize explore by touch:

- Touching the screen to highlight the visual component you are touching, and
- Swiping gesture that moves a cursor to highlight visual components on the screen.

This method of highlighting is called hovering. When a visual component is hovered it can be selected by double tapping the screen. Fig. 4.1 illustrates the use of swiping gestures to hover on items in the list as well as double tap to select the hovered item.

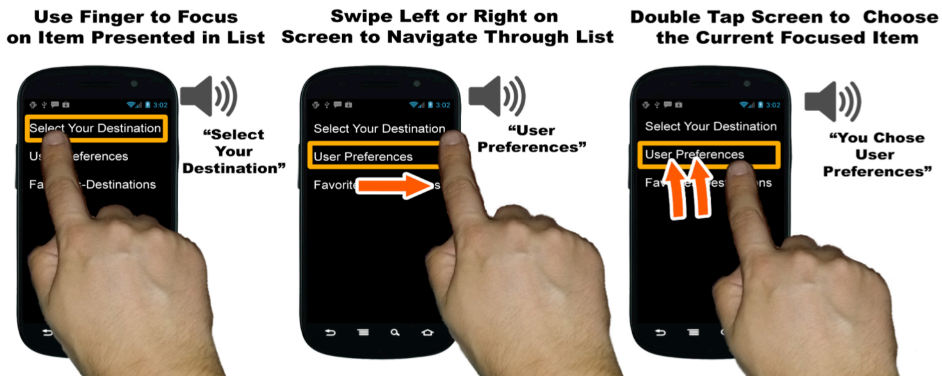

Figure 4.1: Explore by touch user interface

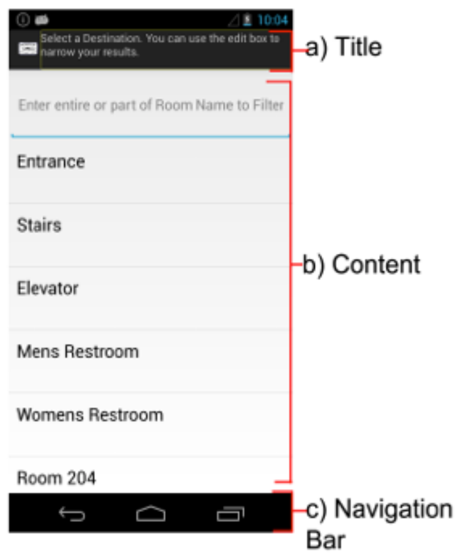

Figure 4.2: User interface layout

It is important that the layout of the user interface aligns with the Accessibility Services available in the Android operating system. By following this design the user can easily identify the purpose of each user interface component, how to interact with it, and its location in the user interface as it relates to the other visual components. The user interface illustrated in Fig. 4.2 includes:

A. Title

This title relays to the user the purpose of this screen. For example, if the activity on this screen involves destination selection, the title will read "Select the destination below". When the user navigates to a new screen, the title is spoken to them. The user immediately knows the purpose of the particular screen state and if at any time needs a reminder can hover over the title bar.

B. Content

The content is the center piece of the user experience. It contains various user interface components that either provide information to the user or allow the user to perform an action. When the user is selecting each component, whether it be through swiping or hovering, the user needs to understand what type of visual component it is. When the user hovers over the button that it will say not only the button name but also the fact that it is a button itself. Users familiar with "Explore by touch" will then realize that this is a clickable object.

As shown in Fig. 4.2, the content is presented in a list. It is important to remember that the end user is consuming this information one by one and therefore the flow of the user interface should be conducive to the way the user is "viewing" the information.

C. Navigation Bar

Navigation Bar includes the universal navigation buttons (Home, Back, and Quick App Navigation) This bar in most cases is always present throughout the Android Visual

Interface. The HOME and APP SELECTION button will pause your application's current app screen and return the user to the home screen or a particular app. The BACK button will close the current activity.

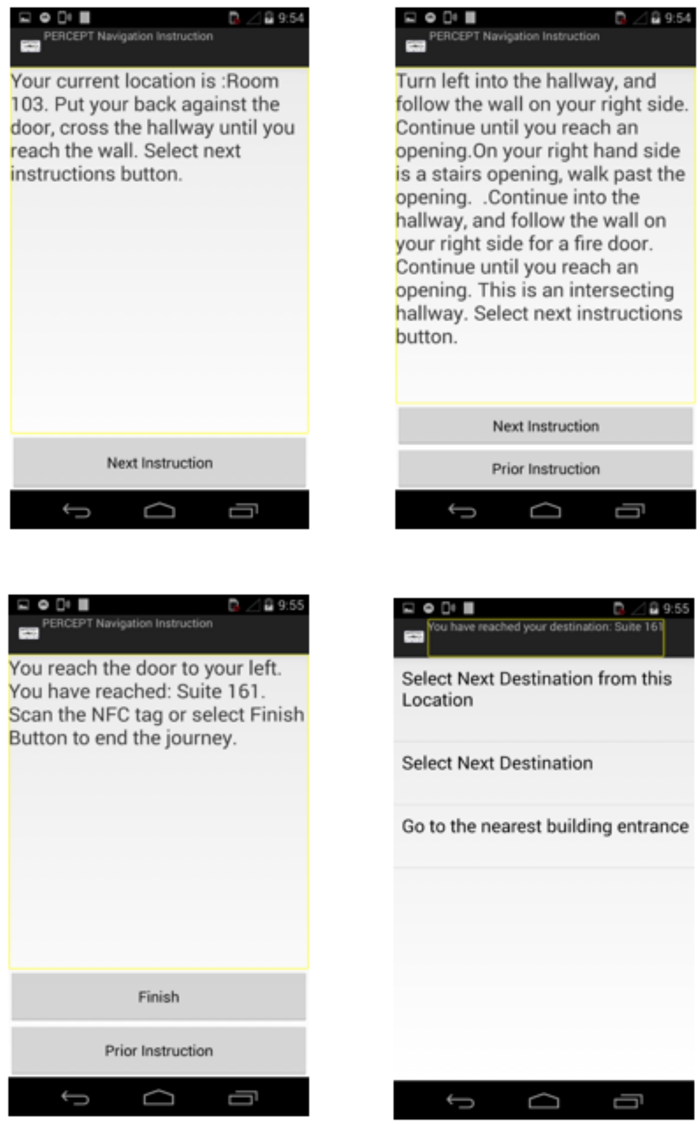

Figure 4.3: Navigation Instruction User Interface

Fig. 4.3 presents user interfaces of navigation instruction activity. The following is the description for the components of its interface.

A. Next Instruction Button

If user arrives landmarks without RFID tags or does not want to scan NFC tags, he or she can click Next Instruction Button to receive next piece of navigation instruction.

B. Prior Instruction Button

The button helps users retrieve the last piece of instruction that they have heard. This could help in the situation that they feel not clear about the context of the current piece of instructions. So they will be able to go back and retrieve all the previous instructions again and get a better understanding of the route.

C. Finish Button

When users reach the last piece of instructions, they will be able to use Finish Button to end the journey.

D. Select Another Destination from This Location

After users have reached their destinations, they will have the option to select next destination starting with current location without finding and scanning the current landmark's NFC tag.

The remaining part of this section introduces the pause and resume functions for playing navigation instructions with accessibility feature. Pause and resume functions are enabled when playing the audible navigation instructions. So users can choose to pause anytime they want when the navigation instructions are playing, and also resume playing whenever they feel comfortable. The pause and resume functions are triggered by three-finger touch gesture on the smartphone screen. With three-finger tapping on the screen, pause function will be called if it's currently playing navigation instructions, and resume function will be called if the playing is already paused or stopped.

Since it's not a built-in feature for Android Operating System, the functionality is achieved by implementing multi-threads of Text-to-Speech engines working simultaneously. The basic process is synthesizing the navigation instructions from text format into audio format (wmv format), then playing them with Android Media player. In order to reduce the time cost for synthesizing the text and improve user experience, the App will have multi-threads working simultaneously. Firstly, the App divides all the instructions into individual sentence. Then assign one thread to synthesize the text into audio format, also assign another thread working on playing the audio simultaneously. Besides this, the feature with synthesizing and playing instructions is integrated with original Android Operating System Accessibility feature given the fact that very few documents or resources are available in this area.

By following the Android Operating System Accessibility Protocols, this feature is compatible with the operating system.

CHAPTER 5

ORIENTATION AND MOBILITY SURVEY TOOL

We have developed a survey and annotation tool which we denote Orientation and Mobility (O&M) survey tool. The tool will be used by the O&M instructor during the time they visit the building in which we plan to deploy PERCEPT system. Using the O&M survey tool the O&M instructor will annotate important sensory landmarks on the building blueprint. This tool will help the O&M instructor collect all the relevant information about each landmark (its location, picture, audio, text, associated NFC tag) and store the information in the database, which is later used to generate the navigation instructions.

We have developed the tool using an Android tablet (Google Nexus 7. Android 4.2.2 Operating System) that has a camera, RFID tag Reader, Wi-Fi 802.11 b/g/n.

Figure 5.1 displays the interface of the O&M Survey Tool.

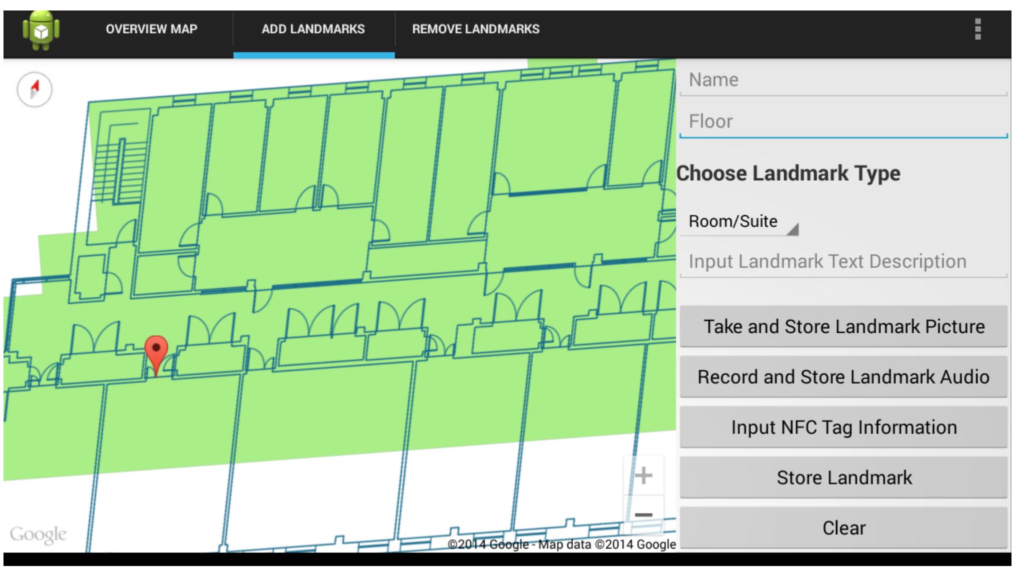

Figure 5.1: O&M Survey Tool Interface

As we can see in the interface, on the left side, there is a blueprint indicating the indoor layout of the building overlayed on Google Map. Each balloon indicates a landmark input as determined by an O&M instructor. On the menu on top of the screen, there are three choices: Overview Map, Add Landmark, Remove Landmark. At the right side of the interface, there are multiple interfaces for O&M Instructors to input landmark information. We provide a detailed description of each function.

O&M instructors can add/delete landmarks on the blueprint. Each landmark will include the following information:

- **Name**: O&M instructor can name the landmark.
- **Floor**: O&M instructor can specify the floor that the landmark is on.
- **Landmark type**: specify it's a room/suite or elevator or stairs or other types.
- **Text annotations:** O&M instructors can use this tool to input any text description for the landmark. This might include providing the description of the surrounding environment. For example, when inputting the entrance of Whitmore Building as a landmark, O&M instructors can input the text description for the lobby area.
- **Audio annotations:** During the collection information process, the O&M Instructor may decide to record audio format information, such as voice or other sounds for future reference. For example, we can record the sound of a vending machine, sounds in a cafeteria, sounds of a printing center, etc. The navigation instructions may also include the text description of sound for users when they reach this

landmark.

- **Picture annotations:** Take a picture of the landmark and store it for future reference. This could provide all the details of the landmark in case the O&M instructor may need them later.
- **Reads NFC tag:** By scanning the NFC tag associated with the landmark, the tag id will be automatically stored and transmitted to the server database along with its associated landmark id. NFC tags can be updated or removed from the database. This scanning can simplify the process of deploying and recording the tags in the building.

CHAPTER 6

TRIALS

In this section we provide an overview of the trial we conducted. The experimental design follows an Internal Review Board (IRB) approved protocol for testing the system with human subjects in Whitmore Building. We have tested the system with 5 blind and visually impaired subjects that were recruited by an Orientation and Mobility instructor from the Massachusetts Commission for the Blind. The testing protocol includes the following three stages: orientation, testing and evaluation. We describe each stage in the following subsections.

6.1 Orientation

At the beginning of the trial, we introduced PERCEPT Application, the NFC tags and their interaction. We have designated a small area of the building as orientation area used during the orientation phase. A mock mini-trial is done by asking the subject to navigate through a number of destinations in the orientation area using PERCEPT system. At any point the subject can stop and ask for help from the test administrator. The orientation is completed when the subject feels comfortable with PERCEPT system. There is no time limit imposed. This stage took between 30 and 60 minutes.

6.2 Testing

Each subject was asked to navigate to eight destinations within Whitmore Building (same sequence of destinations is presented to each subject).

The destinations were located on the first and second floor. The test administrator told the user the destinations, one at a time, i.e., the next destination was given only after the current destination was successfully reached. During this stage the test administrator does not aid the subject with any navigational tasks. However, if the subject's safety was at all compromised, the trial administrator can intervene on behalf of the well being of the subject. If the subject was not able to find a destination, they could ask anyone in the environment to help them, however this was recorded as a failure of PERCEPT System.

We first introduce Pathway A and Pathway B below in Figure 6.1. See the pathways also in Figure 6.2, Figure 6.3, Figure 6.4, Figure 6.5.

Pathway A

(Route 1) Haigis Mall Entrance ----> Disability Service Office ... Suite 161

(Route 2) ----> A & F Administrative System Support ...Suite 150

(Route 3) ----> Womens Restroom

(Route 4) ----> Undergraduate Registrar ... Suite 213

(Route 5) ----> Residential Life Student Services ... Suite 235

(Route 6) ----> Financial Aid Services and Student Employment ... Suite 243

(Route 7) ----> Academic Planning and Assessment ... Suite 232

(Route 8) ----> Entrance Ramp Second Floor

Pathway B

(Route 1) Rear Entrance First Floor ----> Disability Service Office ... Suite 161

(Route 2) ----> A & F Administrative System Support ...Suite 150

(Route 3) ----> Undergraduate Registrar ... Suite 213

(Route 4) ----> Residential Life Student Services ... Suite 235

(Route 5) ----> Financial Aid Services and Student Employment ... Suite 243

(Route 6) ----> Academic Planning and Assessment ... Suite 232

(Route 7) ----> Entrance Ramp Second Floor

Figure 6.1: Trial Pathways

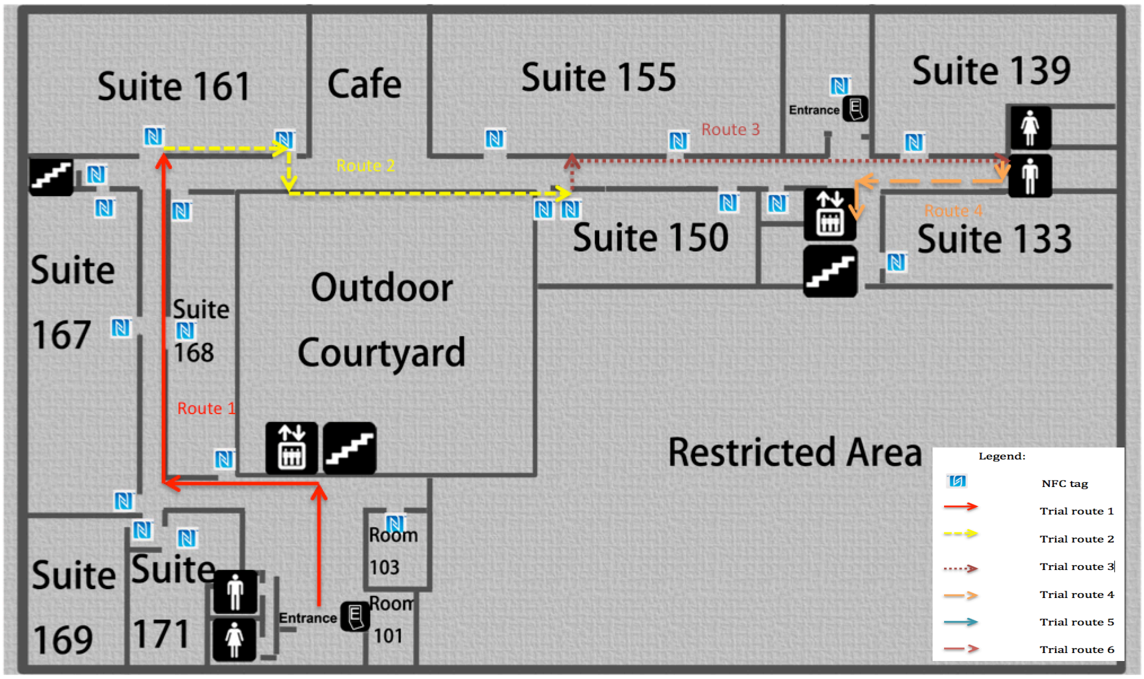

Figure 6.2: Pathway A First Floor

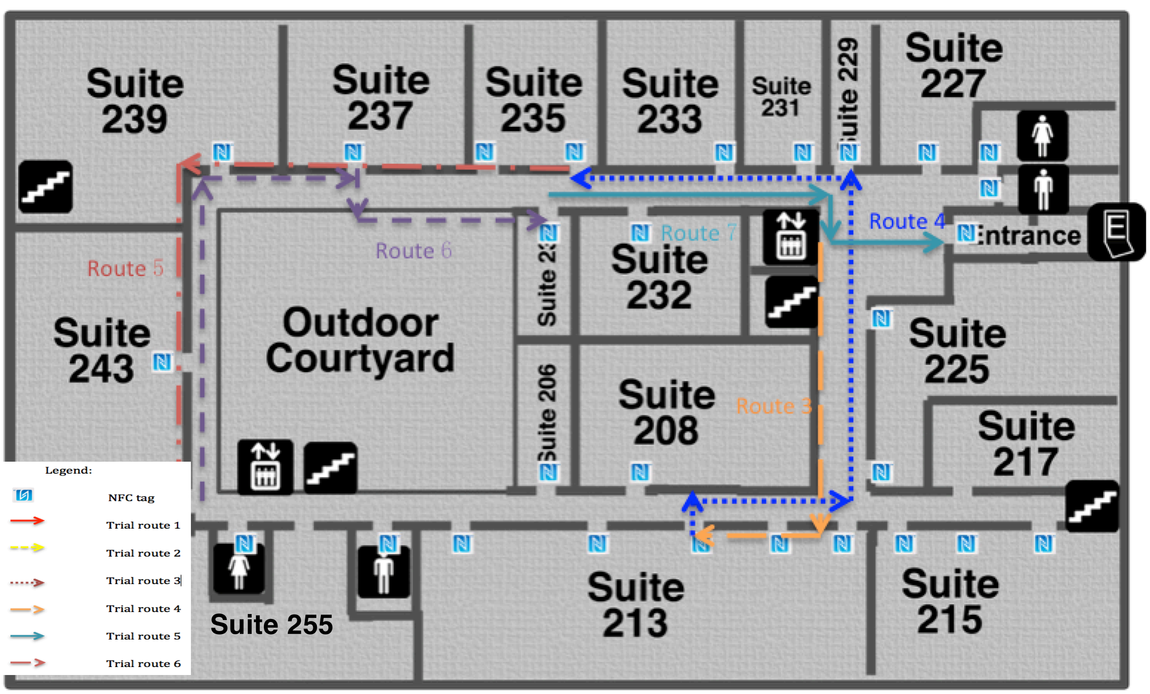

Figure 6.3: Pathway A Second Floor

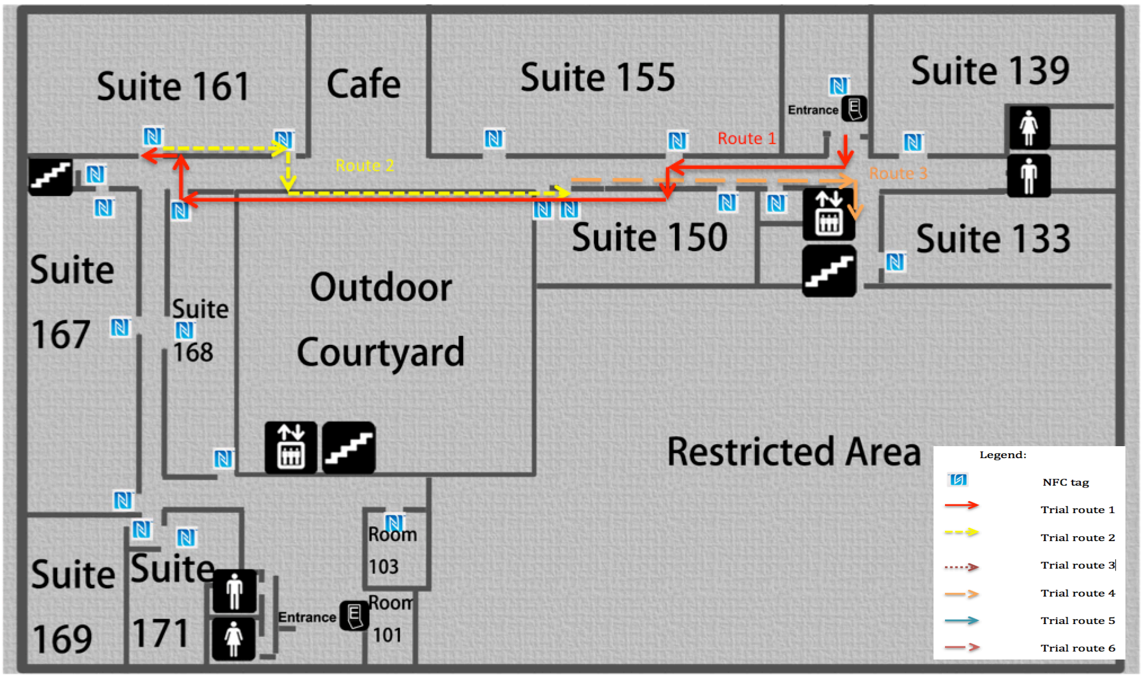

Figure 6.4: Pathway B First Floor

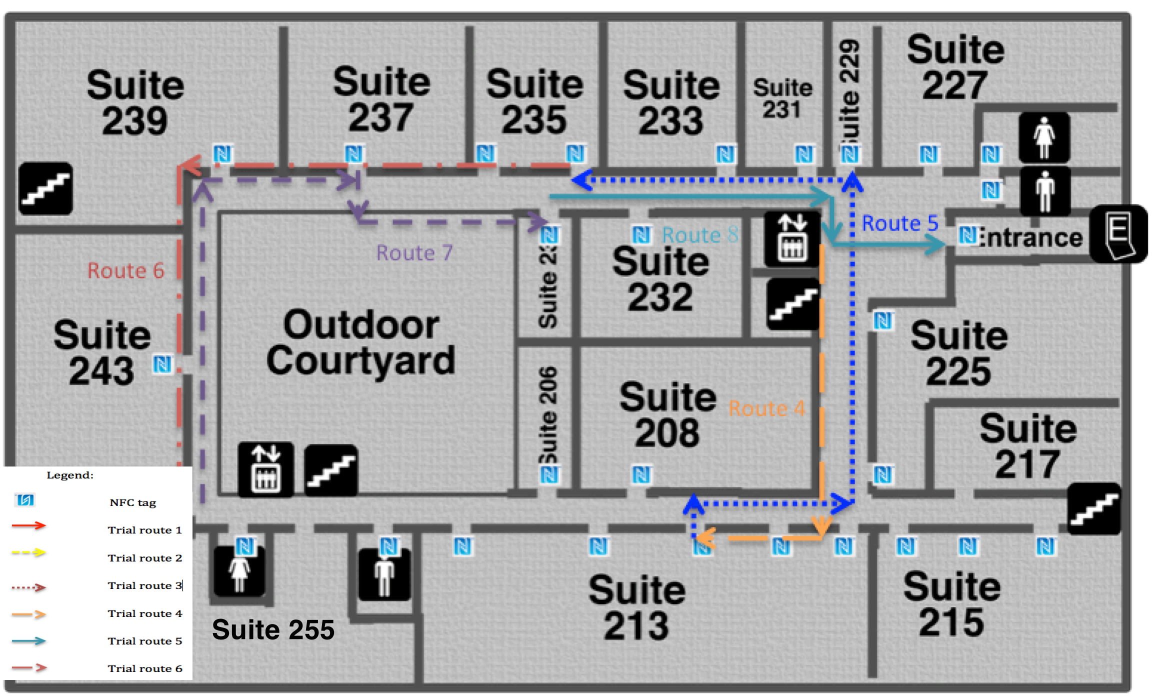

Figure 6.5: Pathway B Second Floor

6.3 Evaluation

Each subject was asked a series of qualitative questions regarding their experience with the PERCEPT system. Here is the IRB approved questionnaire:

Interviewer Conducted Survey

PERCEPT Experiment

Date:____________

We thank you for participating in the PERCEPT experiments. You really helped us test the system and your feedback will help us improve the system design to better serve the blind and visually impaired to navigate independently inside an indoor environment.

Table 6.1: Percept Trial Evaluation Table

	YES	**NO**	**MAYBE**
Did you think that navigation directions given by the system were easy to follow?			
During the course of the trial, did you feel that you were lost inside a building? (This will tell us user-friendliness of system)			

What do you think about the pace of the audio directions? Should the pace be slower or faster or it is good enough? (Highlight the circle of your choice)

- It should be slower
- It should be faster
- It is good enough

What do you think about the User Interface?

- just right
- difficult to use
- needs improvements – provide details

If you could design the system yourself, what is the first thing you would change to make the system more usable?

Table 6.2 and Table 6.3 provides a summary of the 5 subjects' feedback.

Table 6.2: Summary of the Subjects' Feedback

	QUESTION 1: Did you think that navigation directions given by the system were easy to follow?	**QUESTION 2: During the course of the trial, did you feel that you were lost inside a building? (This will tell us user-friendliness of system)**	**QUESTION 3: What do you think about the pace of the audio directions? Should the pace be slower or faster or it is good enough?**
A	Yes	No	It is good enough
B	Yes	No	It is good enough
C	Yes	No	It should be slower
D	Yes	No	It is good enough
E	Yes	No	It should be faster

Table 6.3: Summary of the Subjects' Feedback

	QUESTION 4: What do you think about the User Interface?	**QUESTION 5: If you could design the system yourself, what is the first thing you would change to make the system more usable?**	**QUESTION 6: Please provide us with any improvements that you recommend.**
A	Just right	Organize Destinations by Name	Would like to use voice to input destination
B	Difficult to use	Utilizing the earpiece only as the means for the user interface including voice activated commands	Voice Commands should be a must
C	Needs Improvement: Need to improve the app for those with partial vision, including larger print, higher contrast buttons, and unique colors for the different parts of the doors	Have a repeat button instead of a gesture	Instructions should be broken down even more and read slower
D	Difficult to use	Keyboard Input, not that friendly, improve the friendliness or replace with voice prompts	Elevator button description in the form of the buttons with respect to the row and columns they are in.
E	Closer to just right (would want to change specifying destination) but would use PERCEPT right now	Break instruction steps using swipe gesture instead of a next instruction button	Voice activated destination

We note the following:

- Question 1: All subjects agreed that navigation directions given by the system were easy to follow.
- Question 2: None of the subjects thought that he or she ever felt lost inside a building during the trial.
- Question 3: Three of the five subjects thought the pace was just right, one subject thought it should be faster, one subject thought it should be slower.
- Question 4: One of the five subjects thought the interface is just right, two subjects thought the interface needed improvements, two subjects thought it's difficult to use.
- Question 5: Three of the five subjects thought that the destination input in the user interface is difficult to use. One subject thought the interface should have a repeat button instead of a gesture. One subject thought breaking instruction steps should use swipe gesture instead of a next instruction button.
- Question 6: Three of the five subjects thought that destination input in the user interface should be using voice command. One subject thought that instructions should be broken down even more and read slower. One subject thought that elevator button description should be in the form of the buttons with respect to the row and column they are in.

In summary all subjects thought the navigation instructions were clear and easy to follow. The common improvements being requested were creating a user-friendly way to choose destination in the user interface. All subjects commented that they were able to find the NFC tags and liked the consistency of NFC tag placements.

CHAPTER 7

TRIALS CONCLUSION AND FUTURE WORK

The contributions of this thesis include the design, implementation and testing of a scalable PERCEPT, an indoor navigation system for visually impaired and blind people. It includes navigation instructions generation algorithm, a vision-free smartphone user interface and Orientation & Mobility (O&M) Survey Tool.

Using the navigation instructions generation algorithm presented in this thesis, we can generate the navigation instructions automatically based on the building layout and current instructions vocabulary. Therefore the algorithm could be applied to any building or indoor environment regardless of the size or layout.

We designed a vision-free PERCEPT application using Android accessibility features. Using this vision-free application, the visually impaired users can navigate independently in the building.

We also have developed a survey and annotation tool which we denote Orientation and Mobility (O&M) survey tool. The tool will be used by the O&M instructor during the time they visit the building in which we plan to deploy PERCEPT system.

The system has been tested in Whitmore Building with 5 blind and visually impaired subjects that were recruited by an Orientation and Mobility instructor from the Massachusetts Commission for the Blind. Using PERCEPT system all the subjects successfully reached all the preset destinations (8 destinations in total for each subject) independently.

We propose a number of future extensions for PERCEPT system. First, the system should be extended to include large open space environments. We need to develop a localization method to track users' current location in real-time along with a corresponding navigation instructions generation algorithm.

Second, different users have different levels of understanding the navigation instructions. This extension can include three levels of instructions: slow, medium and fast. For the slow level, the navigation instructions will be chunked into smaller pieces. This means that only one small piece of instructions will be presented to the user at each time. In this way, we will be able to accommodate different user levels.

Third, we can improve the user interface by incorporating voice commands. For example, the user will need to say the destination instead of typing it.

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